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Delaney Spencer
dspenc26@uwo.ca

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Learning the Spatial Layout of a New Real-World Environment

Delaney C. Spencer

Honours Psychology Thesis
Department of Psychology
Brescia University College
London, Ontario Canada
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Thesis Advisor: Dr. Jennifer Sutton

Abstract

Cognitive maps are mental representations of the configuration of landmarks from an environment (Tolman, 1948; O'Keefe & Nadel, 1978). Broad individual differences in the accuracy of cognitive maps exist, however, it is not yet clear what underlies these differences (Weisberg et al., 2013). In the current study, participants first completed a spatial perspective-taking task called the Spatial Orientation Test (SOT; Hegarty & Waller, 2004). They then were taken on a guided walking tour of an unfamiliar area of campus where they were asked to remember the names and locations of eight target landmarks. Participants' ability to create a cognitive map of the area was assessed by having them estimate the direction between the target landmarks and draw a sketch map of them. A linear regression showed that spatial perspective-taking performance on the SOT was an accurate predictor of accuracy on the direction estimation task.

Learning the Spatial Layout of a New Real-World Environment

A helpful tool to navigate a new environment efficiently is making a mental representation of the environment being learned (Tolman, 1948). This concept known as a cognitive map, which only some individuals are able to create, provides more information about the overall environment than just a simple route or single path (O'Keefe & Nadel, 1978). More specifically, cognitive maps are a mental representation of an environment that are created to help with navigation by providing memory of the configuration of the landmarks from the environment (Tolman, 1948; O'Keefe & Nadel, 1978). These maps can aid in the navigation of detours and choosing the most logical route to use to arrive at a desired destination (Bennett, 1996; Kitchin, 1994). They are also used in other spatial decisions such as shortcutting, which is defined as choosing the route that takes the shortest time to get from point A to point B. There is even evidence for the presence of cognitive maps in less sophisticated animals such as dogs, hamsters, and rats (Chapuis, Thinus-Blanc, & Poucet, 1983; Tolman, 1948).

After animal researchers claimed that animals used cognitive maps to navigate, Bennett (1996) reviewed a group of papers and created an alternate theory. He believed that animals that were thought to be showing shortcutting were actually using landmarks; such as trees, rocks, or other objects, to orientate themselves around the goal which they had been familiarized with during training. During the task, the animals had to recognize the landmark from an alternative angle and move towards it in order to reach the target. According to Bennett (1996), to accurately test for cognitive maps it must be certain that path integration is not being used to perform shortcuts. Path integration is combining distance and direction when moving, which allows animals, and humans alike, to move in a straight line towards a goal. In order to prove the existence of cognitive maps, the animal should not be able to see the goal while shortcutting

(Bennett, 1996). This can make it difficult to prove the existence of cognitive maps in animals, but in humans pointing tasks can be used to show true shortcutting.

Over the years, theories on the “how” and “who” develops cognitive maps have progressed toward a better understanding of spatial navigation. Siegel and white (1975) were two of the first to study spatial navigation and cognitive maps in humans. They hypothesized that it takes time and continued exposure to the new environment in order for humans to form an accurate representation of space. In 1997, Siegel and White proposed a three-stage model of building a spatial representation. Landmark knowledge, the first stage, is the ability to recognize distinct objects and use them to navigate a new environment. All the landmark knowledge of the environment is then combined to create knowledge of the routes, which is then combined to create the final stage; survey knowledge (Siegel & White, 1975). However, Montello (1998) argues that there is not a stage where only landmark or route knowledge purely exists but rather; knowledge starts from first exposure in order to create a mental representation. This suggests that these representations are improved upon and become more accurate with increased exposure to the environment, which would explain why some individuals are instantly accurate on spatial navigation tasks (Montello, 1998).

Early on in this field of research, there were many conflicting theories about cognitive map development in humans. In one instance, Siegel and White (1975) proposed that in the early stages of learning a new environment only non-metric knowledge is present. This would suggest that individuals in this stage would not be able to answer simple questions regarding the distance between buildings in a new environment (Montello, 1998). Worchel (1951) provided evidence against this by using blind subjects. The participants, after walking along angled paths, were able to walk in a straight line back to the starting spot. This demonstrated that they had some sort of

metric knowledge of the environment in order to correctly return to the start while unable to use visual information. Another way to show that metric knowledge is present within a single exposure to a new-environment is pointing tasks. Montello (1993) had college students walk around and learn two separate routes that were not visibly related. The participants were given a description that allowed them to integrate the two routes together and then performed pointing tasks. Using metric knowledge, the participants were able to accurately point towards the target without being able to see it (Montello, 1993). These two tasks of straight-line walking and pointing support Montello's theory that information about a new-environment is not broken up into stages but instead happens all at once.

Cognitive maps can be difficult to study in a real-world environment as large-scale, novel environments are not always available and can be time consuming to study. When technology became readily available it became the main method to study cognitive maps in an efficient manner. Weisberg, Schinazi, Newcombe, Shipley, and Epstein (2013) were interested in how individuals learn in a virtual environment opposed to a real-world environment. In Silcton, a virtual environment, participants learned two separate routes. The participants' ability to make judgments within a single route and judgments between the two routes were tested using pointing tasks. These tasks had participants to stand at a location either within the same route, or in a different route and point to a target landmark that was not in their visual view. Using these results, Weisberg et al. (2013) proposed there was three types of navigators: integrators, non-integrators, and imprecise navigators. Integrators were participants who were accurate in both "between" and "within" route judgments. They had the ability to create a mental representation of the environment by combining their knowledge of the separately learned routes in order to navigate (Weisberg et al., 2013). The participants who performed well at "within" but not

“between” route judgments, non-integrators, were not able to create a mental map that incorporated the two routes. They knew the routes individually, as they were able to chain together landmarks to create routes, but were unable to combine the two routes to create a mental representation. Finally, imprecise navigators were poor at both “within” and “between” route judgments (Weisberg et al., 2013). It was not shown how these results would differ in a real-world environment and why some individuals are better than others at integrating routes to form a cognitive map.

In order to understand navigation of a new environment, individual differences in the development, or lack thereof, of cognitive maps should be considered. Weisberg and Newcombe (2016) elaborated on their previous research, examining what the development of a cognitive map is dependent on. They found that those who were imprecise navigators also had both low spatial and verbal working memory capacity. This would explain why imprecise navigators performed poorly on both types of pointing tasks as they are not able to effectively learn the building’s names and locations, especially when paired. Weisberg and Newcombe’s (2016) study also found no difference of working memory in integrators and non-integrators. However, the integrators maintained route information as well as, or better than non-integrators. This individual difference in the ability to maintain route information may be the reason why some individuals develop cognitive maps and some do not.

Virtual environments allow for cognitive maps to be examined relatively quickly, however, the results may not translate to a real-world environment. Ishikawa and Montello (2006) used a real-world environment to test how individuals form cognitive maps and how they differ with route integration. For once a week for 10 weeks participants were blindfolded and driven to the start of the new environment. Each time they were driven down two routes twice in

either the opposite or same direction and after the fourth trial they were driven down a connector route. The participants were instructed to remember the name and location of two buildings along each main route (Ishikawa & Montello, 2006). Before and after each trial participants were administered the Santa Barbara Sense-of-Direction Scale (SBSOD) which asked questions regarding the participants feelings towards their spatial navigation skills. A sketch map task, which required participants to draw where each target building was located, and a pointing task, where participants had to estimate the location of buildings out of their visual field by pointing to it, were also administered after each session. Ishikawa and Montello (2006) found participants overall ability was the same or better with each trial, and performance on the tasks were consistent across all sessions. Not only does this support Montello's (1993) proposal that cognitive maps form with initial exposure to a new environment but also meets Bennett's (1996) requirements for proving the presences of a cognitive map.

Although Ishikawa and Montello (2006) findings supported previous literature, it may not extend to all situations involving navigation. In this study, the participants were passengers in a car and the researcher drove them down the routes. By having participants be the passenger they are using passive spatial learning opposed to active (Ishikawa & Montello, 2006). Appleyard (1970) studied spatial knowledge of bus drivers compared to the passengers. The study found that drivers have a higher level of spatial knowledge compared to passengers who only had basic route knowledge. Regardless of the participant driving or being the passenger, by being in an automobile they are not able to use proprioceptive information used in active spatial learning. Motor and proprioceptive information contributes to the integration of paths in large-scale environments (Chrastil & Warren, 2011). This type of information is associated with active learning and is not acquired in passive learning such as driving or virtual simulations. Ishikawa

and Montello's (2006) study supported the idea of cognitive maps, however, a study is needed that is less time consuming than their study as it took weeks to complete, and that focuses on cognitive maps in a real-world environment. As well, a method to study navigation in a large-scale environment using active, opposed to passive, spatial learning is needed to prove the presence of cognitive maps in all types of navigation.

In the current study participants were taken on a guided walking tour of a campus, which they had not previously visited. Similar to the Ishikawa and Montello (2006) study participants were taken on two separate routes, and a connector route where they were instructed to remember the name and location of eight buildings. Before the guided tour, the participants completed the Spatial Orientation Test (SOT), which was used as a predictor of the post tour tasks. Other studies, such as Weisberg et al. (2013), used a SBSOD as their predictor. However, the SBSOD is a self-report that may not be reliable compared to the SOT that tests the person's ability to imagine different orientations in space. Furthermore, SBSOD is a poor predictor of "within" route pointing tasks and the SOT may be a more accurate alternative (Weisberg et al., 2013).

Once participants completed the SOT, they were guided along an indirect path to the start of the first route where Brescia University College, their home campus, could not be seen. From there the participants were administered a written pointing task to ensure they were not using landmarks, such as Brescia's campus, to orientate themselves. This task, as well as the indirect route, ensures participants were truly using a cognitive map and not landmarks to complete the tasks (Bennett, 1996). Once the guided tour was completed participants were administered the Huron Direction Estimation Task (DET) and sketch map task, where participants were not able to see any of the target buildings. By not having the visited buildings visible it eliminated the

chances of the effects being caused by land marking, which is a problem in the commonly used on-site pointing task. The inability to landmark meets Bennett's (1996) criteria for building a cognitive map. We hypothesized that direction estimation ability and spatial orientation ability would be correlated, and that spatial orientation performance would predict performance on both Huron tasks. As well, the Huron tasks would also be correlated to the orientation task and to each other. Finally, it was hypothesized that spatial orientation performance would show less errors than on the direction estimation performance, as this task relied on memory of the environment.

Method

Participants

A total of 26 female participants were recruited for this experiment, with an average age of 19 years old. The participants were University students enrolled in Introduction to Psychology at Brescia University College and were recruited using Brescia Psychology Research Participation System (SONA). They were given one credit for every 30 minutes of compensation.

Material

Demographic Questionnaire. The participants provided information about their gender, degree of familiarity with Huron's campus, and how long they have lived in London. The questionnaire included questions about the frequency of any video games they played in order to determine whether gaming was associated with performance on the tasks (see Appendix A).

Spatial Orientation Test (SOT; Hegarty & Waller, 2004). The SOT is a paper-and-pencil test that includes 12 items. Each item has an array of objects in the top half, and a circle in the bottom half of the page. The circle contains a label in the middle indicating where the participant should imagine they are standing, and an arrow pointing to the object they should

imagine facing based off the array of objects presented to them. The participants were asked to indicate the direction of a third object by drawing a line from the middle to the edge of the circle. They had five minutes to complete as many of the 12 questions as they could.

Brescia Orientation Task. The participants stood at the edge of a tunnel facing towards Huron College's dining hall where Brescia University College cannot be seen, while they completed this paper-and-pencil task. The participants were asked to draw a line from the middle to the edge of the circle to indicate the direction of Brescia University College from where they were standing. This tested how well the participants were able to stay orientated to their starting point during the indirect walk to Huron College (see Appendix B).

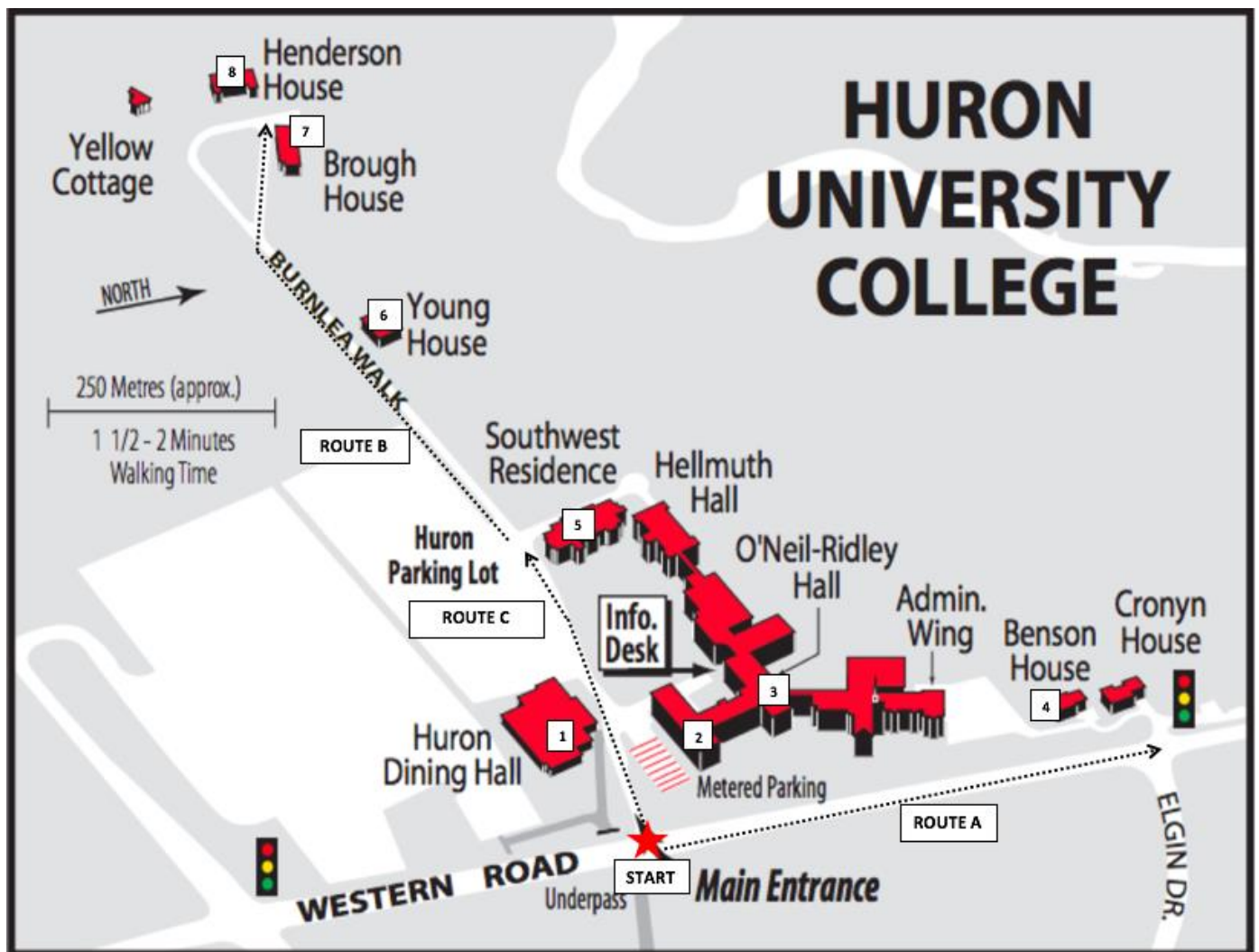
Huron Direction Estimation Task (DET). This task was similar to the SOT with the exception that the DET used landmarks the participant visited at Huron College, as opposed to an array of random objects. As well, the DET used the participants memory of the layout of landmarks on the Huron campus, opposite to the SOT where the target objects were always visible (see Appendix C). This task is based on the offsite pointing task from Weisberg et al. (2013).

Huron Sketch Map Task. This task provided an empty rectangle on the top half of a page for participants to draw and a list of names of the Huron landmarks were provided on the bottom half of the page. This was to ensure errors in the map were not due to the inability to recall the names of the target buildings. Participants were asked to draw a map of Huron's buildings from a bird's eye view by memory. They marked buildings with an 'X' and labeled it with the letter from the legend found at the bottom of the page (see Appendix D). The Huron Sketch Map task was analyzed using the Gardony Map Drawing Analysis.

Procedure

The participants met the researcher at Brescia University College where they received a letter of information and provided informed consent. The demographic questionnaire was then given to participants with unlimited time to fill it out and return it to the researcher. The participants were then given the Spatial Orientation Test to be completed with paper and pen. The researcher reviewed the instructions of the task and an example problem with the participants. Unlimited time was given to participants to read the instructions themselves, to ensure their understanding of the task before beginning. They had five minutes to complete as many of the 12 questions as possible. Once completed, participants walked with the researcher to Huron University College using an indirect path going through main campus (see Appendix E). Once at the Huron tunnel, the participants were asked to complete the Brescia Orientation Task with unlimited time.

Participants were then taken on a walking tour of Huron's campus guided by the researcher, which included two main routes and one route and one counter route (see Figure 1). Participants were asked to remember the name and location of four target buildings along each main route, for a total of 12 buildings. The researcher stopped the participants at each building, pointed at it, and said its name out loud. The tour started at the end of the tunnel where the Brescia Orientation Task was conducted, from there participants were taken along the first main route (route A) and back. This route included the Dining Hall, O'Neil Ridley Hall, the Chapel and Lucas Alumni House. Once participants walked the opposite direction on route A and returned to the start of the route they were taken down the connector route (route C), starting at the Dining Hall and ending at the Southwest Residence. This is where the second main route (route B) began, this route included Southwest Residence, Young House, Brough House, and Henderson



Number	Building Name
1	Dining Hall
2	O'Neil-Ridley Hall
3	Chapel
4	Lucas Alumni House
5	Southwest Residence
6	Young House
7	Brough House
8	Henderson House

Figure 1. Map of Huron College's campus including the target buildings, route A, route B and route C which is the connector route. The star indicates the starting point of the walking tour.

House. After traveling in the opposite direction on route B, the participants were led down the opposite direction of the connector route (route C) to the beginning of route A.

After the exploration of Huron, the participants were taken to Huron's library, where they were given two more paper-and-pencil tasks. The Huron Direction Estimation Task was administered first and participants had unlimited time to complete all eight questions. Once completed and returned to the researcher, participants were given the Huron Sketch Map task, where they had unlimited time to label and mark all buildings. Finally, participants were given a debriefing form, which they were encouraged to take with them.

Results

A correlation analysis was conducted to investigate associations between the participant's level of familiarity with Huron's campus, weekly video game playing frequency, and scores on the SOT, Huron DET, Huron Sketch Map and Brescia Orientation Task (see Table 1). Participants' familiarity with Huron's campus was scored on a scale from zero to four, with zero indicating the participant was completely unfamiliar with the campus and four indicating they had been to Huron more than six times. The participants weekly video gaming frequency was coded as (0) never play, (1) less than once per week, (2) one to two times per week, (3) three to four times per week, (4) five to six times per week and (5) more than six times per week. The SOT, Huron DET and Brescia Orientation Task were scored as the mean absolute error, thus lower scores indicate better performance. A significant moderate, negative correlation was found between familiarity with Huron's campus and the Huron DET. This indicates that participants who were more familiar with the campus made fewer mistakes on the Huron DET than those who were less familiar. As well, a significant moderate, positive correlation between the Huron DET and the SOT was found, indicating that participants performance on the SOT was similar to

their performance on the Huron DET. However, there was no significant correlation found between the SOT and the Huron Sketch Map. There was a significant moderate, positive correlation found between scores on the Huron DET and gaming frequency. This indicates that as frequency of video game playing increased, errors on the Huron DET also increased. Finally, there was no significant correlation found between the two Huron tasks, or between the Brescia Orientation Task and the Huron DET.

A linear regression analysis using Enter method was conducted to examine the extent to which the scores on the SOT could predict scores on the Huron DET (see Figure 1). The regression model accounted for 17% of the proportion of variance in the Huron DET score, $R^2 = .17$, $F(1, 24) = 5.05$, $p = .034$. It was found that the score on the SOT was a significant predictor of the score on the Huron DET, $\beta = .42$, $p = .034$.

Finally, a paired t-test was conducted between the SOT and the Huron DET, which found no significant difference between the means of the two tests, $t(25) = -.15$, $p = .885$, $d = 0.03$. This indicates participant's accuracy on the SOT was similar to their accuracy on the Huron DET.

Discussion

The current study showed that as mistakes on SOT increased so did mistakes on the Huron DET, and that scores on the SOT could be used to accurately predict scores on the Huron DET. These findings support the hypothesis made that tasks that test the ability to imagine different perspectives in space would be related. This association between these measures indicate that perspective taking skills are important whether people are being tested on arrangement of items that is kept in view or whether it is an arrangement of items stored in

Table 1.

Means, Standard Deviations, and Correlations for Huron Sketch Map, Huron DET Error, Brescia Orientation Error, SOT Error, familiarity with Huron's campus, and Gaming Frequency.

	Familiarity with Huron	Huron measures				<i>M</i>	<i>SD</i>
		DET	Sketch Map	SOT	BOT		
Familiarity with Huron	—					.27	.45
Huron DET	-.45*	—				50.07	19.13
Huron Sketch Map	.09	-.35	—			.68	.16
SOT	-.32	.42*	.12	—		49.28	29.28
Brescia Orientation Task (BOT)	-.24	.07	-.18	.04	—	24.87	27.57
Gaming Frequency	-.20	.44*	-.07	.10	-.10	.88	1.45

Note. * $p < .05$, ** $p < .01$, *** $p < .001$. $N = 26$. Huron DET, SOT and Brescia Orientation Task are scored as mean error, so higher values indicate worse performance.

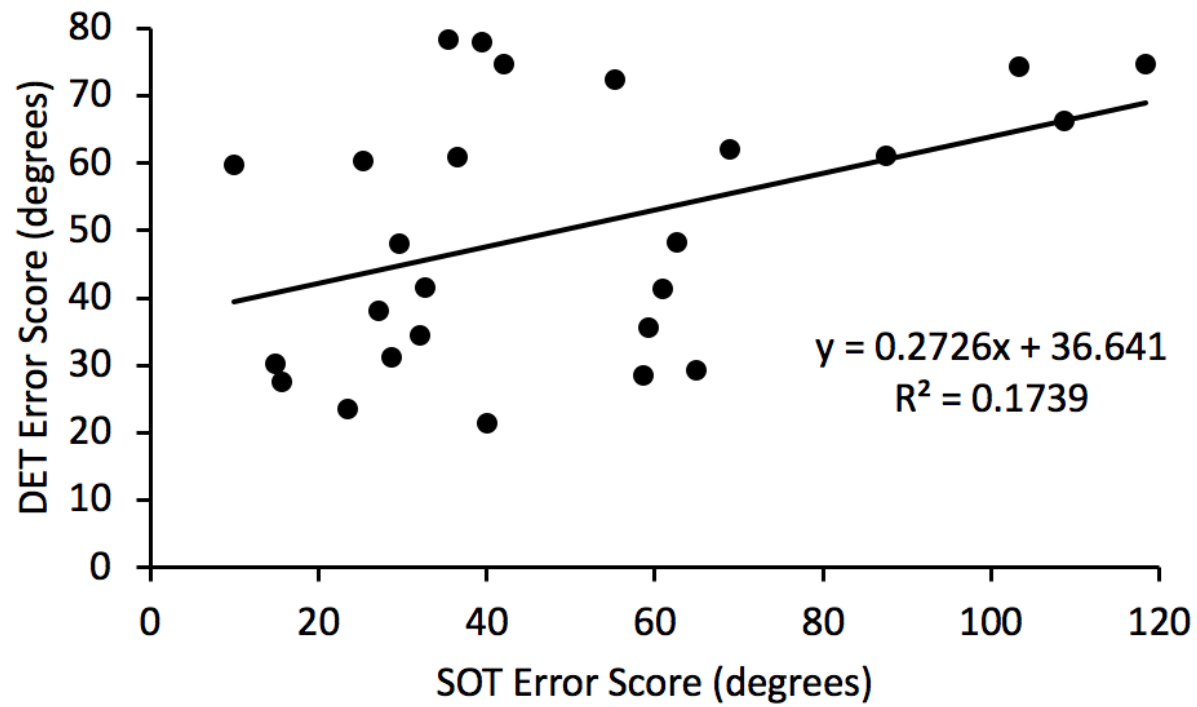


Figure 2. A scatterplot showing the line of best fit for the SOT and DET error scores.

memory. The findings also support the hypothesis that perceptive taking tasks could predict perceptive taking ability when using memory of a space after active learning. However, it was also hypothesized that spatial orientation ability, such as that in the SOT which had all items present during testing, would be stronger than tasks that rely on memory of a space after active learning like the Huron DET. There was no evidence found to support this hypothesis. There was also no evidence to support the hypothesis that tasks that rely on memory of a space after active learning would be related, since performance on the two Huron tasks were not correlated. As well, no evidence was found to support the hypothesis that the Brescia Orientation Task would increase accuracy on both Huron tasks. The current study also found a relation between familiarity with Huron's campus and mistakes on the Huron DET, which suggested that as familiarity increased the errors on the pointing task decreased. Finally, there was evidence that found that as gaming frequency increased, errors on the Huron DET also increased.

Participants who performed well on the SOT also performed well on the Huron DET as hypothesized. Both of these tasks tested orientation and perceptive taking abilities, which is the ability to imagine different viewpoints of a scene (Hegarty & Waller, 2004). Hegarty and Waller (2004) found that mental rotation, such as used in the SOT, and perspective taking, which is dominantly used in the Huron DET, were greatly related and that the SOT was a reliable measure. These findings support those found in the current study, which found a relationship between the SOT and the Huron DET.

When studying cognitive maps, the dominate measure in past studies has been sketch maps, but the current study's findings suggests this may not be the best measure of cognitive map accuracy. Rovine and Weisman (1989) found that sketch maps were the best predictors of way-finding, including orientation, sense of direction, and visualization which is the ability to

imagine the movement of objects (Hegarty & Waller, 2004). The SOT, Huron DET, and Brescia Orientation Task all focus on these three factors, however, the current study found no correlation between sketch mapping and any of these mentioned tasks. In one study, participants studied a map then were asked to draw it from memory and complete spatial orientation tasks involving landmarks and routes (Coluccia, Losue & Brandimonte, 2007). The study found a relationship between sketch maps and their spatial tasks, which were similar to the Huron DET and the Brescia Orientation Task, but despite the measures similarities the current study's findings do not support a link between sketch map accuracy and other spatial measures. This finding is supported by Montello, Waller, Hegarty and Richardson (2004), who hypothesized that sketch maps do not require as much space knowledge as a pointing task, such as the Huron DET. The ability to indicate the direction of a non-visible landmark requires knowledge of the surrounding environment layout and a combination of landmark knowledge. Sketch maps, however, do not require any of this and do not have the same capabilities as pointing tasks (Montello, et al., 2004). This indicates that sketch maps may not be the most accurate way to assess for cognitive maps, as they may not have the test validity they were thought to hold.

The ability to stay orientated to the starting point location of the study was hypothesized to be a key component of participants' accuracy on the Huron DET, although the current study found no evidence to support this hypothesis. This finding was supported by literature such as Kozlowski and Bryant's (1977) study. The study concluded that in order to be a precise navigator, ongoing conscious effort to orient oneself is required. In the Brescia Orientation Task, participants ability to stay orientated was tested by asking them to locate Brescia after following an indirect route to Huron. However, since the participants were not aware they would be tested on their ability to stay orientated they may not have made an ongoing conscious effort to stay

oriented to Brescia. This supports Kozlowski and Bryant's (1977) findings, as the current study found no relationship between the Brescia Orientation Task and any other spatial ability tasks. How well the participant stays orientated is important as Brescia can be seen from different location on Huron's campus, thus landmarks, such as target buildings, could be encoded spatially relative to Brescia rather than relative to other landmarks in Huron.

In the past, the SBSOD has been used as a predictor of spatial ability such as that tested in pointing tasks (Weisberg et al., 2013). However, the SBSOD are self-reports and therefore are not very reliable. The study also found that SBSOD were not significant predictors of spatial ability. Kozlowski and Bryant (1997) found that pointing tasks could be used to examine spatial orientation. It was hypothesized that the SOT would be an accurate predictor of performance on the Huron DET, as the SOT does not just ask the participants about their spatial abilities, but actually tests them. The current study's findings support this hypothesis and found that as errors on the SOT, errors on the Huron DET also decreased. As supported by Kozlowski and Bryant (1997), the SOT is testing the same abilities as the Huron DET making it an accurate predictor of real-life navigation.

An interesting finding that was not hypothesized showed that as familiarity with the campus increased, errors on the Huron DET decreased. This finding supports Montello's (1998) New Framework which states that as exposure to environment increases, there is an increase in quantity, accuracy and completeness of spatial knowledge. This means that as participants have more experience with Huron's campus, they can build on to their spatial knowledge to make their cognitive maps more accurate.

Despite not being hypothesized, the current study's findings showed that as video game frequency increased, mistakes on the Huron DET also increased, however, there was no effect of

video games on the SOT which measures the same abilities as the Huron DET. This finding contradicts previous literature which have found video games improve spatial abilities (Feng, Spence & Pratt, 2007). A study interested in testing if video games that use spatial skills could improve scores on a spatial ability task, found that only certain video game could enhance these skills (McClurg & Chaille, 1987). These spatial ability tasks included mental rotation, which is used in the SOT, however, no relationship was found between the SOT and video games in the current study. Similar results were found in another study conducted by Feng et al., (2007). They found participants who played action video games had improved spatial attention and mental rotation ability. As well, this finding was more prominent in females compared to males. These results suggest that the current study's findings may be due to the all-female population used, as well as problems with questions regarding video game frequency. These questions may not have been specific enough in regard to type of video games played, as many participants reported cell phone games such as 'Subway Surfer' which use minimal spatial skills. The findings may have been different if the questioned asked about specific video games which used spatial skills, such as mental rotation or navigation rather than any video game frequency.

Including the accuracy of the questionnaire, there were other limitations that could have influenced the interpretation of data in the current study. For example, the comparison between the SOT and Huron DET tasks reveals further complications. For the SOT, the participants were asked to start at a point in the middle of a circle and draw a line to the edge of the circle when indicating the direction of a target object. This allowed for a consistent starting point across all trials for each participant as well as a consistent basis for the researcher to interpret results. Moreover, by having a consistent starting point it allowed for accurate comparisons between participants. Although the Huron DET is similar the SOT, it did not have a single starting point

for each trial. Instead, the Huron DET just had the name of a Huron building previously visited by the participant. The participant was instructed to imagine themselves standing at the location in the center of the circle. However, by not having a uniform starting point, the participant may have determined that they could start from anywhere around the name of the building when drawing a line to the location of one of the target buildings. This led to participants all having different starting points for the same trial, making comparisons to one another difficult and less accurate in the data analysis.

The Huron DET also differs from the SOT as the SOT only requires participants to draw a line to single target location. The Huron DET requires participants to draw lines in the direction of six target buildings. This means not only did some participants have a different starting point than each other for the same trial, but within a single participant's trial there may have been multiple starting points. This is a problem as for each trial the participant was instructed to imagine themselves at the building in the center of the circle when drawing the lines to the six target buildings. This means there should only have been a single starting point as the center was the same building within a trial. By having multiple starting points within a single trial, it makes it difficult for the researcher to accurately interrupt where the participant thought a target building was located. Such a dilemma also made it difficult for the researcher to be consistent when measuring all six lines in a single trial. For future studies, pointing tasks such as the Huron DET should have a single starting point and clear instructions as to where to start and finish drawing the line.

Future research could explore a more diverse population of both males and females, as there may be a cultural and sex differences in the ability to build and use cognitive maps. It may also be beneficial to study how individuals remembered the buildings names. There were

participants who tried to actively remember the building name and location by repeating the name out loud in a certain order, or by making acronyms. This requires more attention and may have benefited the participants. Finally, since there was a relationship found between familiarity and scores on the Huron DET, it may be interesting to examine if familiarity is an accurate predictor of navigation ability and the development of cognitive map accuracy. This could be done by changing the exposure of the environment for different groups of participants, allowing the researcher to control how familiar the participant is with the environment.

To sum up the findings, tasks that test the ability to imagine a different perception or orientation in space, such as the Huron DET and the SOT, were related and the SOT was found to be an accurate predictor of the Huron DET. It was also found that familiarity with the environment was related to direction estimation tasks between land marks, and the most surprising of the findings was the relationship between video game frequency and errors on the Huron DET. Although, there are limitation to this study, such as minor issue involving the measures and external factors, this study's findings may help guide future studies in the direction of familiarity and gender differences. This study concludes that cognitive map accuracy can be predicted and tested in a real-world environment in a short period of time.

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Appendix A

Participant # _____

1. Age: _____

2. Sex

☐ Female ☐ Male

☐ You don't have an option that applies to me. I identify as (please specify): _____

3. Current Year in University

☐ 1st year ☐ 2nd year ☐ 3rd year ☐ 4th year ☐ 5th year

☐ Other (please explain): _____

4. How long have you lived in London (Please be specific ex. months/years)? _____

5. Are you familiar with Huron's Campus?

☐ Yes ☐ No

If you answered No, please skip to the next question, below.

If you answered Yes:

Overall, how familiar are you with Huron's Campus? Please circle one:

Not At All
Familiar

Slightly Familiar

Moderately
Familiar

Very Familiar

Extremely
Familiar

6. Do you play video games (for example using a phone, computer, iPad or other tablet, console such as Wii, Playstation, Xbox, Kinect, or other)?

☐ Yes ☐ No

If you answered No, please skip to End of survey, below.

If you answered Yes:

Overall, how often do you play? Please circle one:

Less than once
per week

1 – 2 times per
week

3 – 4 times per
week

5 - 6 times per
week

More than 6
times per week

Which game(s) do you play on a regular basis? (Please list all)

Appendix B

Participant #:

Brescia Orientation Task:



Here

Appendix C

Participant # _____

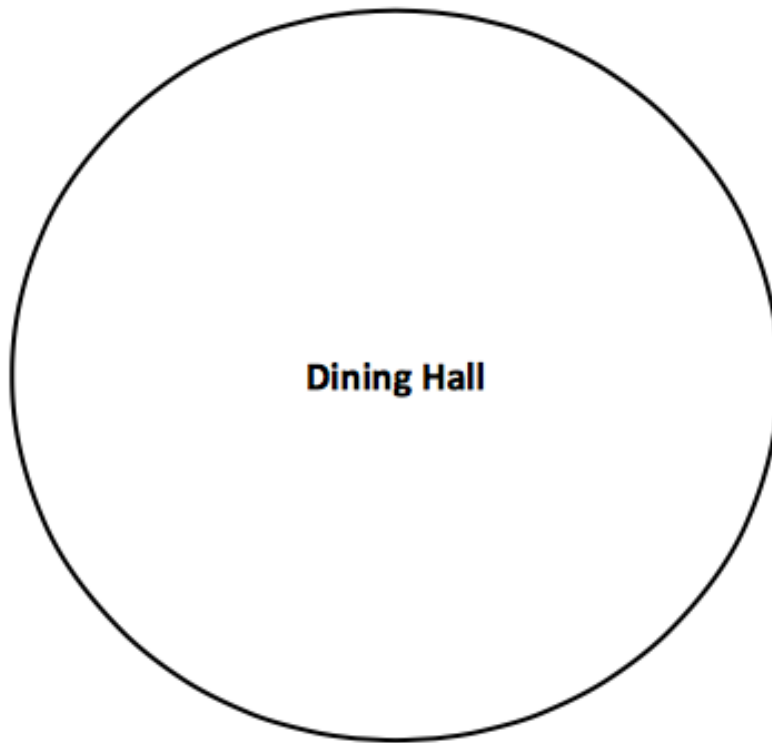
Researcher initials: _____

Direction Estimation Task

Instructions: The next task is another perspective taking task similar to the one you just did with the cat, stop sign and car. In this task you will imagine you are standing at one of the locations you saw at Huron during exploration in the centre of the circle facing another one of the locations you saw at the top of the circle. Then, you will need to draw and label six arrows from the centre of the circle to the outside of the circle indicating the direction of the other six locations you found during exploration given the specific orientation of the building in which you are standing and facing.

Trial #1

O' Neil Ridley Hall



Dining Hall

Directions: Imagine you are standing at Dining Hall facing O' Neil Ridley Hall draw and label 6 arrows to each of the buildings below. (Please write the complete names of each location.)

Benson House

Brough House

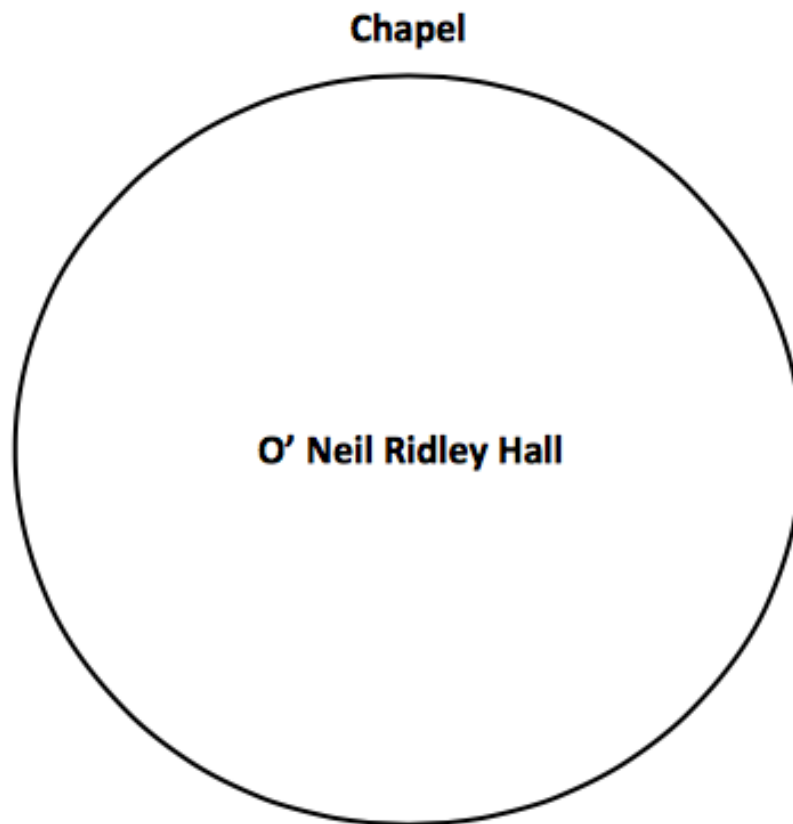
Chapel

Henderson House

Southwest Residence

Young House

Trial #2



Directions: Imagine you are standing at O' Neil Ridley Hall facing the Chapel draw and label 6 arrows to each of the buildings below. (Please write the complete names of each location.)

Benson House

Brough House

Dining Hall

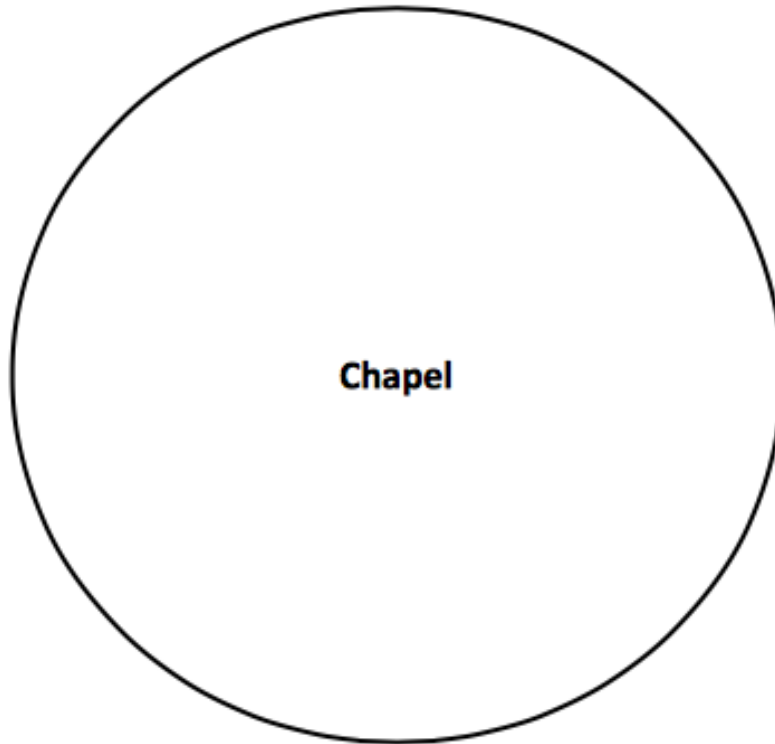
Henderson House

Southwest Residence

Young House

Trial #3

Benson House



Directions: Imagine you are standing at the Chapel facing Benson House draw and label 6 arrows to each of the buildings below. (Please write the complete names of each location.)

Brough House

Dining Hall

Henderson House

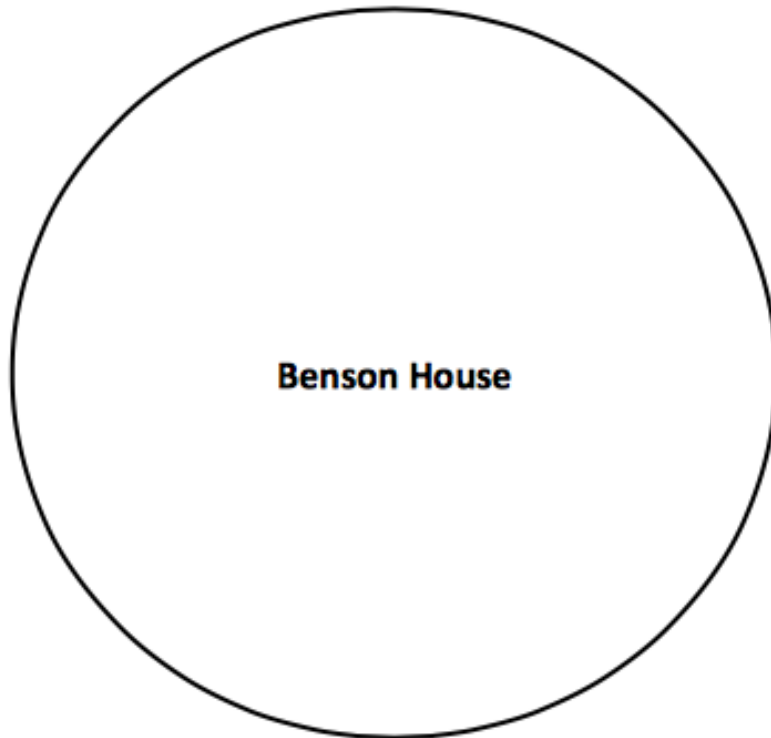
Southwest Residence

O'Neil Ridley Hall

Young House

Trial #4

Dining Hall



Benson House

Directions: Imagine you are standing at Benson House facing Dining Hall draw and label 6 arrows to each of the buildings below. (Please write the complete names of each location.)

Brough House

Chapel

Henderson House

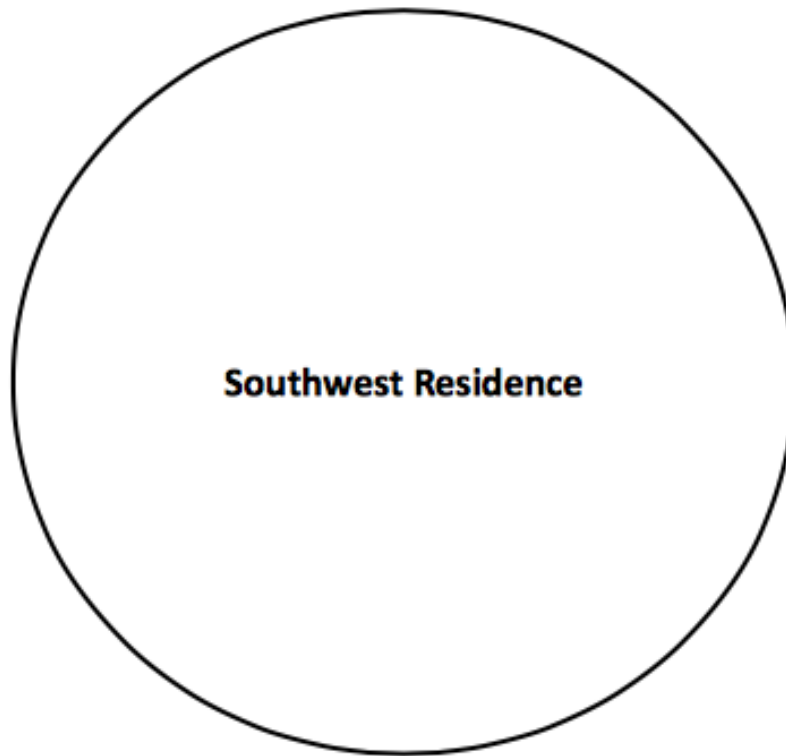
Southwest Residence

O'Neil Ridley Hall

Young House

Trial #5

Young House



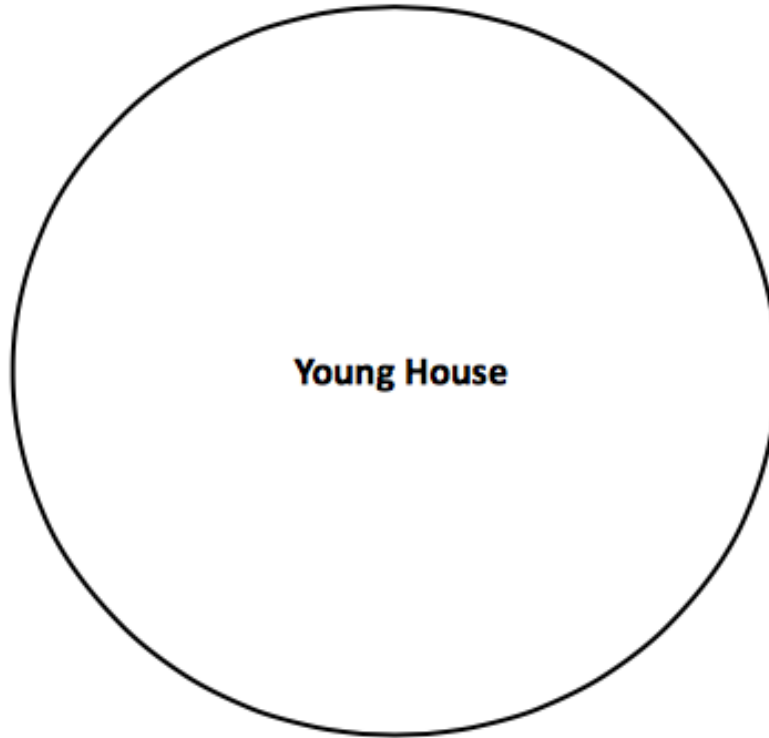
Southwest Residence

Directions: Imagine you are standing at Southwest Residence facing Young House draw and label 6 arrows to each of the buildings below. (Please write the complete names of each location.)

- Benson House
- Brough House
- Chapel
- Dining Hall
- Henderson House
- O'Neil Ridley Hall

Trial #6

Brough House



Young House

Directions: Imagine you are standing at Young House facing Brough House draw and label 6 arrows to each of the buildings below. (Please write the complete names of each location.)

Benson House

Chapel

Dining Hall

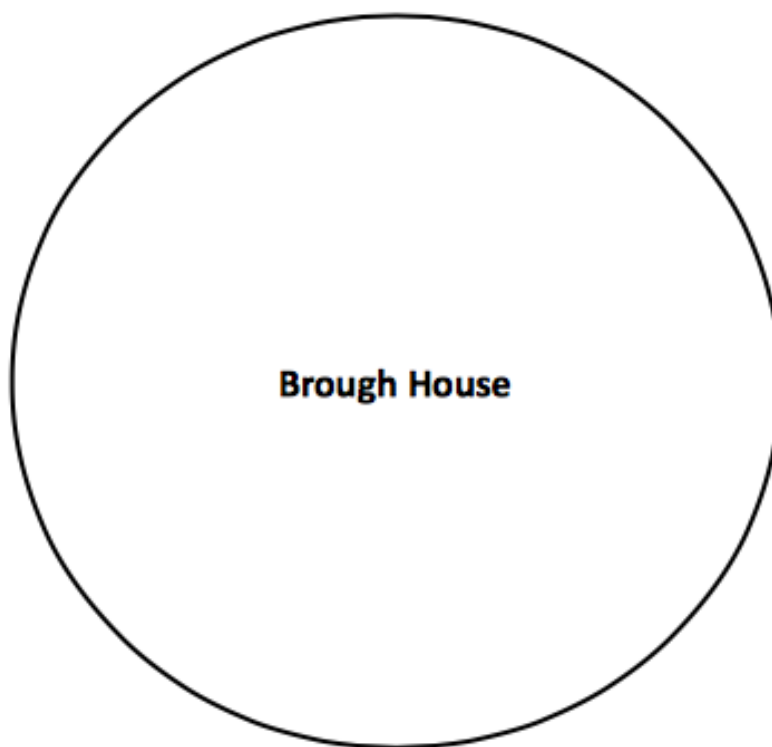
Henderson House

Southwest Residence

O'Neil Ridley Hall

Trial #7

Henderson House



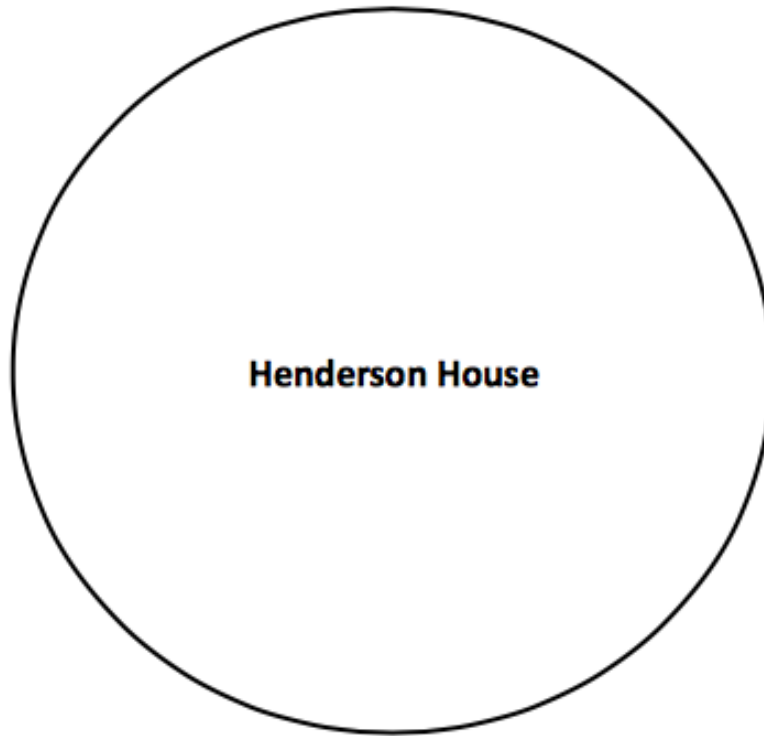
Brough House

Directions: Imagine you are standing at Brough House facing Henderson House draw and label 6 arrows to each of the buildings below. (Please write the complete names of each location.)

Benson House
Chapel
Dining Hall
Southwest Residence
O'Neil Ridley Hall
Young House

Trial #8

Southwest Residence



Directions: Imagine you are standing at Henderson House facing the Southwest Residence draw and label 6 arrows to each of the buildings below. (Please write the complete names of each location.)

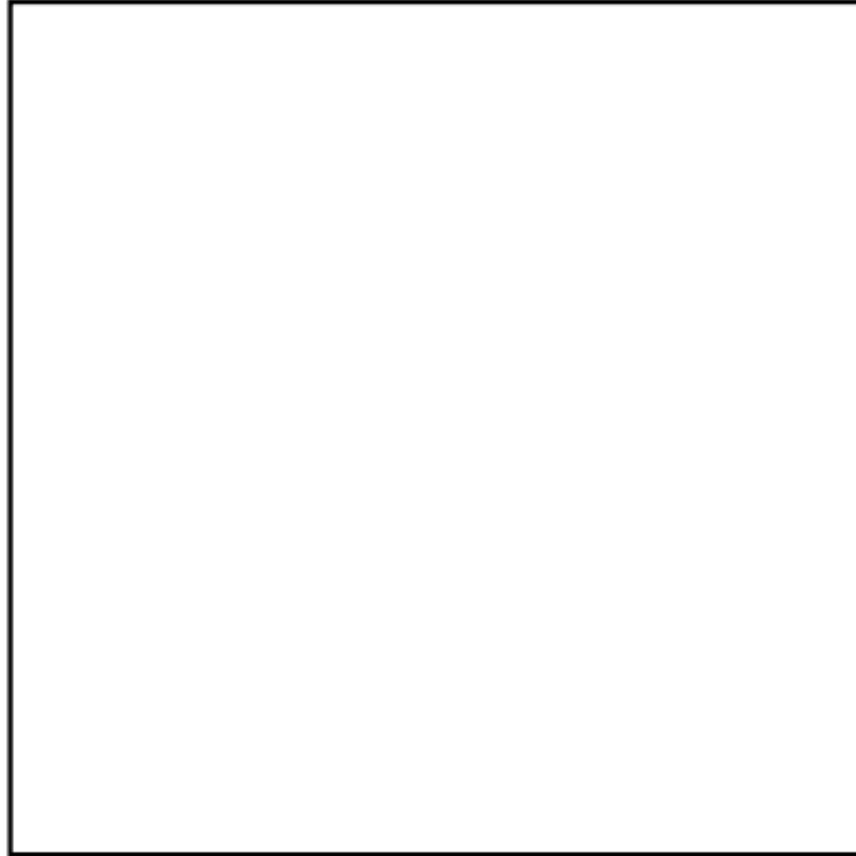
Benson House
Brough House
Chapel
Dining Hall
O'Neil Ridley Hall
Young House

Appendix D

Participant # _____

Huron Sketch Map

North



Directions: Draw an aerial map of the eight Huron locations previously seen during exploration. You may draw each location as a shape (i.e. Square or rectangle), just be sure to mark an “X” by each one and label it with the correct letter below (A, B, C, D, E, F, G, and H). You may also draw additional buildings, roads, or landmarks if that helps you in drawing your map, just be sure the eight locations are clearly labelled.

Legend	Location
A	Lucas Alumni House
B	Brough House
C	Chapel
D	Dining Hall
E	Henderson House
F	Southwest Residence
G	O’Neil Ridley Hall
H	Young House

Appendix E

